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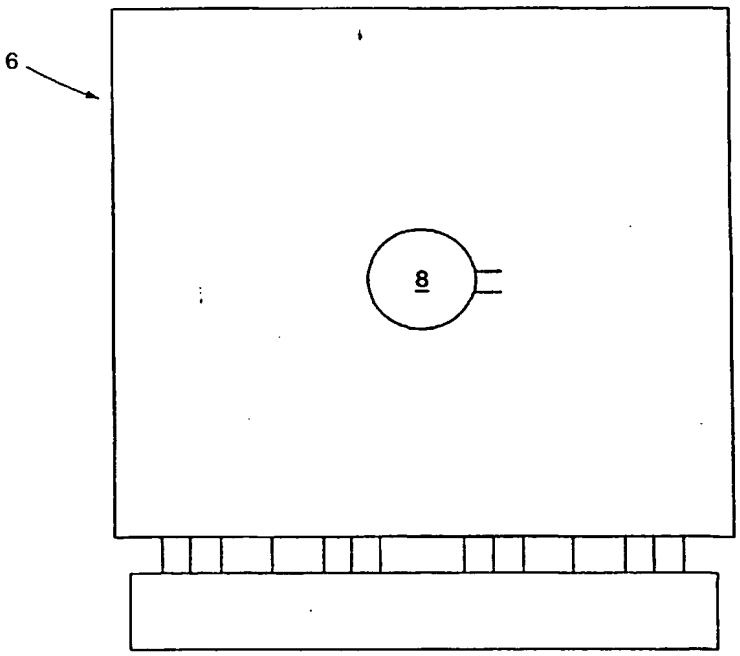

(57) Abstract: A loudspeaker for use with a portable electronic device including a display, the loudspeaker comprising a flexible electronic display element (6), such as a plastic liquid crystal display element, and a transducer (8) attached to the display such that the transducer causes the display to vibrate when an excitation signal is output from the transducer.

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A LOUDSPEAKER

This invention relates to a loudspeaker and in particular to a loudspeaker suitable for use with a portable electronic device including a display, such as a mobile radio telephone.

Conventionally loudspeakers comprise an electromechanical transducer for converting variations of electrical energy into corresponding variations of acoustic energy by mechanical movement and so generate sound waves. These sound waves are amplified by a diaphragm. Loudspeakers may be fairly bulky and there has been a drive to reduce the bulk of loudspeakers so that they may be incorporated into smaller and smaller devices.

Generally an electromechanical transducer is used suitable for exciting a member having the capability to sustain and propagate input vibrational energy. The transducer typically comprises a motor coil assembly, a magnet assembly disposed concentrically with respect to the motor coil assembly, and means suspending the magnet assembly for axial movement relative to the motor coil assembly. A carrier supports the motor coil assembly and is adapted for connection to the member to be excited.

The inventors have realised an alternative way to provide a compact speaker.

In accordance with the invention there is provided a loudspeaker for use with a portable electronic device including a display, the loudspeaker comprising a diaphragm and a transducer, the diaphragm comprising a flexible electronic display element having electrical connectors for receiving electrical signals representing information for display on the electronic display element and the transducer being attached to the electronic display element such that the transducer causes the electronic display element to resonate/vibrate when a mechanical excitation signal is output from the transducer.

The invention results in a compact loudspeaker since the diaphragm is provided by the electronic display element and the transducer is attached to the display element. Thus a separate acoustics device is no longer necessary. Preferably the transducer is placed on the face of the display element that is not to be viewed by a user.

Preferably the transducer is an electromechanical transducer.

A loudspeaker according to the invention is particularly advantageous since there is no need for the provision of audio egress apertures in a device incorporating such a loudspeaker. Thus the device is likely to be more waterproof and dustproof than conventional devices which do require such apertures.

Preferably the electronic display element is a liquid crystal display, most advantageously one made of a plastics material. The electronic display element may be substantially planar and may be foldable.

To increase the audio output level of the loudspeaker, an array of electromechanical transducers may be provided on the flexible electronic display element, the excitation signal being input to each transducer.

In accordance with a second aspect of the invention there is provided a loudspeaker comprising a transducer and a liquid crystal display device, the liquid crystal display device comprising a first flexible substrate, electrode circuitry and electrical circuitry disposed on the first flexible substrate, a second substrate, the first and second substrate being arranged in a mutually opposing planar relationship and a liquid crystal material disposed between the first and second substrates, wherein the transducer is fixedly attached to the liquid crystal display device such that mechanical movement of the transducer is transmitted to the liquid crystal display device causing the liquid crystal display device to vibrate.

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a front plan view of a portable electronic device incorporating a loudspeaker in accordance with the invention;

Figure 2 shows a front plan view of a loudspeaker in accordance with the invention;

Figure 3 shows a cross-sectional view of the loudspeaker of Figure 2 along the line A-A;

Figure 4 shows a rear plan view of the loudspeaker of Figure 2; and

Figure 5 shows a second embodiment of a loudspeaker in accordance with the invention.

Figure 1 shows an example of a portable electronic device including a display. The device shown is a portable radiotelephone, however the invention is applicable to many other applications. The portable telephone comprises a housing 1, display area 2 and a user interface 3 in the form of a keypad. Other forms of user interface may be used, such as a joystick, roller key or touch screen.

In accordance with the invention the display area 2 also provides the loudspeaker functions of the device.

Figure 2 shows a front plan view of a loudspeaker in accordance with the invention. The loudspeaker 4 comprises a flexible display element 6, such as a liquid crystal display (LCD) element, and an electromechanical transducer 8 (see Figure 3). The LCD element 6 acts as a diaphragm for the transducer 8. The flexible display element is capable of sustaining and propagating vibrational energy input thereto by the electromechanical transducer 8.

The liquid crystal display device 6 comprises a first flexible substrate 64 and a second flexible substrate 68. The first flexible substrate 64 has first and

second opposing sides and electrode circuitry 62 and electrical circuitry 63 is disposed on the first side of the first flexible substrate 64. Information for display on the electronic display element 6 is input to the electrical circuitry in the form of electrical signals. The first substrate 64 and the second substrate 68 are arranged in a mutually opposing planar relationship and a liquid crystal material 65 is disposed between the first and second substrates.

A circuitry pattern is formed on the inner surface of the first flexible substrate 64. The electrical circuitry comprises electrode segments 62 and electrical connectors 63. The electrode elements 62 can be activated to form features displayed on the LCD element 6. A typical example of a seven-segment feature is shown, which may be used to represent alpha-numeric characters. For simplicity, the only two such features are shown on the LCD element of Figure 2. However it will be clear to a person skilled in the art that, in practice, the LCD element is capable of displaying many such features at a time and many varieties of feature other than alphanumeric characters e.g. graphical features.

Each electrode element 62 has an electrical connector 63 that connects the electrodes 62 to a driver circuit 9. The driver circuit 9 may be provided on the same face of the substrate 64 as the circuitry pattern 62, 63. Alternatively, the driver circuit 9 may be provided on the rear face of the substrate 64 or elsewhere.

The electrode elements 62 and electrical connectors 63 may be formed in any conventional manner e.g. by depositing a layer of indium/tin oxide on the substrate 64 and etching it using conventional photolithography. The substrates 64, 68 are typically made of thin plastic material, for example polyester.

As can be seen in Figure 3, the second flexible substrate 68 may also have electrical connectors and electrode elements 69 deposited thereon. The

second substrate 68 is bonded to the first substrate 67 using a sealant 67 around the perimeter of the substrate. The sealant 67 is typically an epoxy or other type of adhesive used to hold the two substrates together and also to seal in liquid crystal material 65. Additional elements, such as spacers between the two substrates, may be used to maintain the separation between the two substrates.

An example of a suitable liquid crystal display device is the Sharp plastic LCD LH155p. This plastic LCD has sufficient flexibility to be excited by the multifunction transducer from Tokin MMA-15N-1 and to sustain and propagate vibrational energy input thereto by the electromechanical transducer 8. For a portable telecommunications device such as a radiotelephone, a 40x30mm thick LCD having a thickness of 0.6mm may be suitable.

Figure 4 shows a rear plan view of the loudspeaker in accordance with the invention. An electromechanical transducer is provided on the rear face of the LCD element 6. The coil of the transducer 8 is attached to the LCD element 6 by means of adhesive. The adhesive should have minimum elasticity to avoid any acoustic loss. Connectors 10 are provided to provide an excitation signal to the transducer 8.

When an electrical excitation signal is supplied to the electro-magnetic transducer 8, the electrical excitation signal is converted into a mechanical movement of the transducer. This mechanical movement (or mechanical excitation signal) is transferred to the flexible LCD element 6 since the coil of the transducer is fixed firmly to the LCD element. The LCD element 6 therefore vibrates and forms longitudinal sound waves which are centred on the area of the LCD to which the transducer is attached, as shown in Figure 3.

This has the benefit that the loudspeaker does not operate as a single point sound source, as is the case with conventional loudspeakers in portable

devices. Instead the signal from the transducer is distributed across the flexible display element.

While preferred embodiments of the invention have been illustrated and described, it is clear that the invention is not intended to be limited to these examples. Numerous modifications will occur to those skilled in the art without departing from the spirit and scope of the present invention as defined in the claims. For example, if a greater audio output is required than could be provided by a single transducer of a given weight and size, an array of transducers 8 may be provided on the display element 6, the audio excitation signal being fed to each of the transducers via connectors 10. An example of such a loudspeaker is shown in Figure 5. The transducers 8 produce vibrations in the flexible display element 6 as shown by the dotted lines 50.

The invention is applicable to monochrome display elements as well as colour display elements.

The device shown in the drawings is a portable radio telephone. However the invention is applicable to many other devices with displays, such as other portable telecommunications devices, personal digital assistants (PDAs), laptop computers and personal computers. The examples of devices with which the invention may be used are not intended to be limiting.

Claims

1. A loudspeaker for use with a portable electronic device including a display, the loudspeaker comprising a diaphragm and a transducer, the diaphragm comprising a flexible electronic display element having electrical connectors for receiving electrical signals representing information for display on the electronic display element and the transducer being attached to the electronic display element such that the transducer excites the electronic display element when a mechanical excitation signal is output from the transducer.

2. A loudspeaker according to claim 1 wherein the electronic display element is a liquid crystal display.

3. A loudspeaker according to claim 1 or 2 further comprising a plurality of electromechanical transducers attached to the electronic display element.

4. A loudspeaker according to any of claims 1 to 3 wherein the flexible display element is substantially planar.

5. A loudspeaker according to any of claims 1 to 4 wherein the transducer is an electromechanical transducer.

6. A loudspeaker comprising a transducer and a liquid crystal display device, the liquid crystal display device comprising a first flexible substrate having first and second opposing sides, electrode and electrical circuitry disposed on the first side, a second substrate, the first and second substrate being arranged in a mutually opposing planar relationship and a liquid crystal material disposed between the first and second substrates, wherein the transducer is fixedly attached to the liquid crystal display device such that mechanical movement of the transducer is transmitted to the liquid crystal display device causing the liquid crystal display device to vibrate.

7. A device incorporating a loudspeaker according to any preceding claim.

8. A portable device incorporating a loudspeaker according to any of claims 1 to 5.

9. A portable radio communications device incorporating a loudspeaker according to any of claims 1 to 5.

10. A loudspeaker substantially as described herein with reference to any of the accompanying drawings.

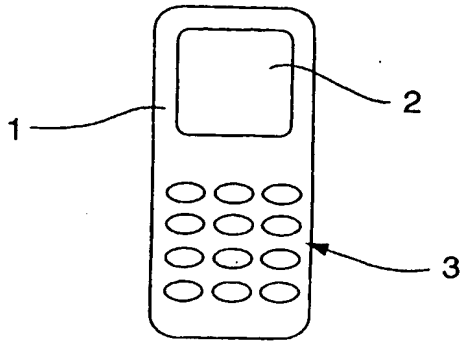

FIG. 1

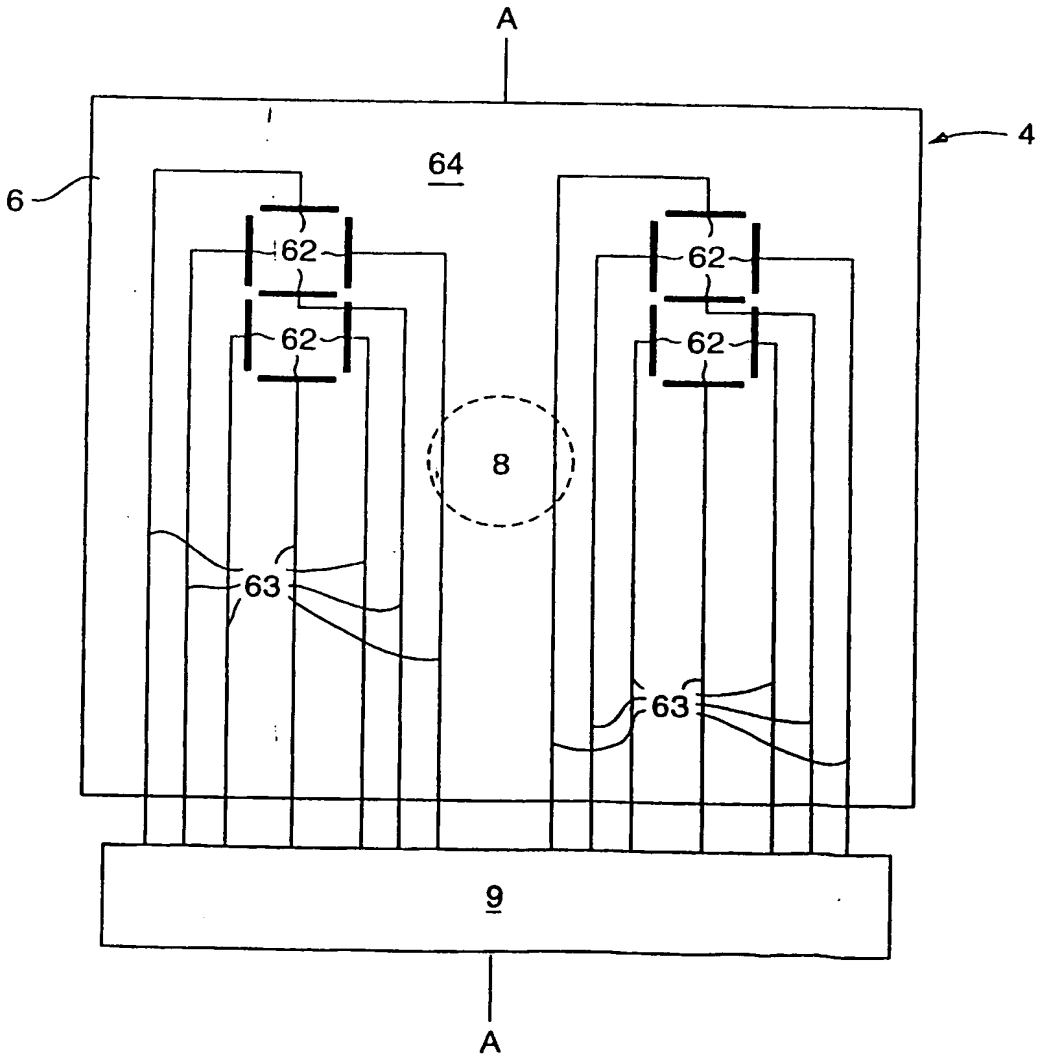

FIG. 2

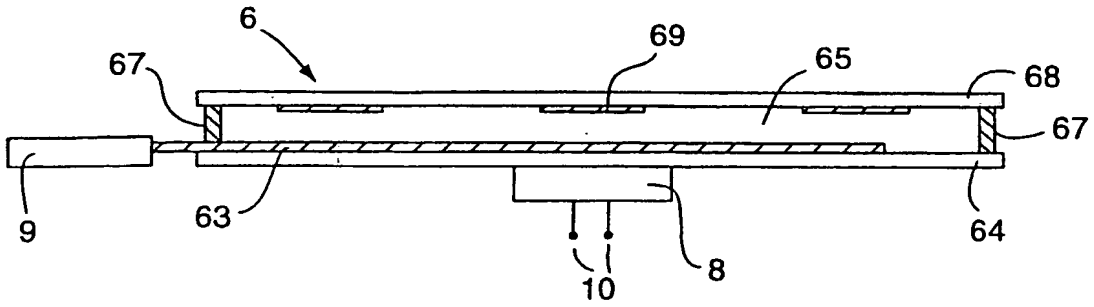

FIG. 3

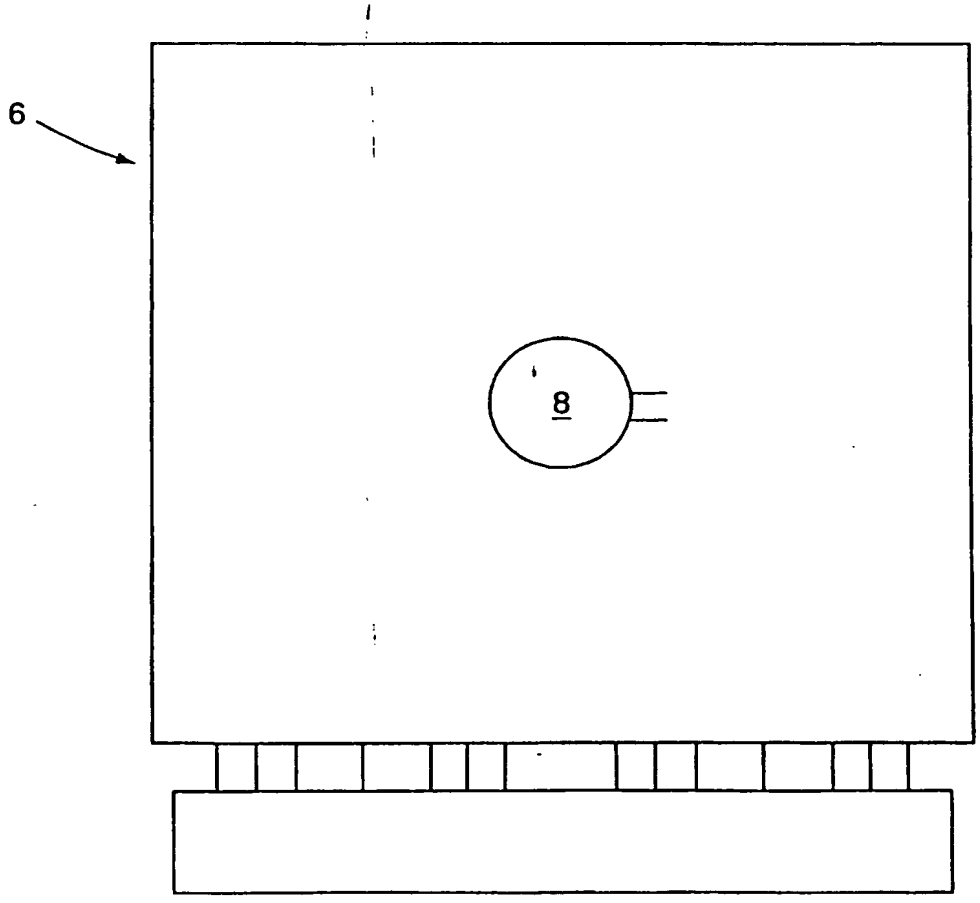

FIG. 4

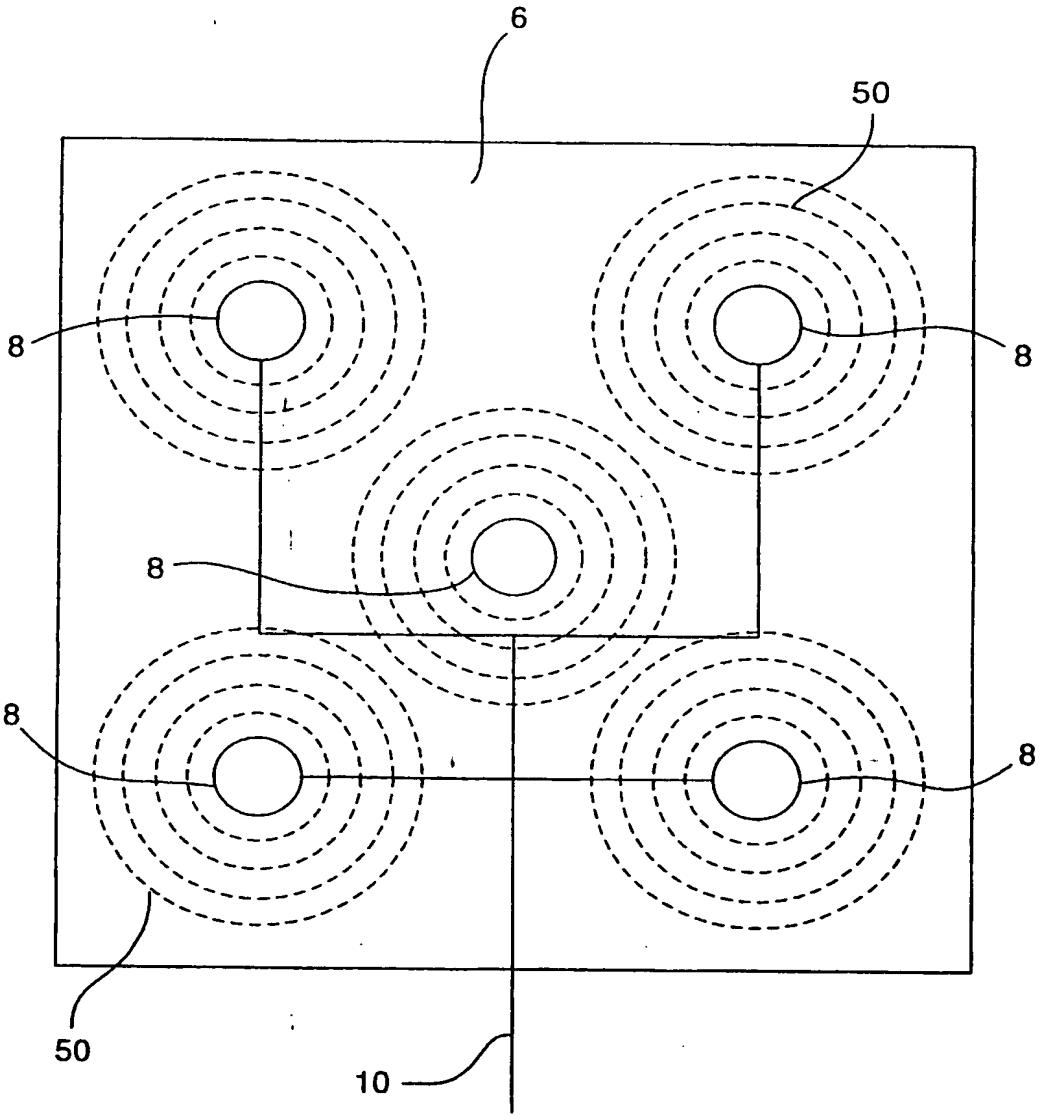

FIG. 5